Exploring indoor air quality challenges in non-notified urban slum: A case study from India

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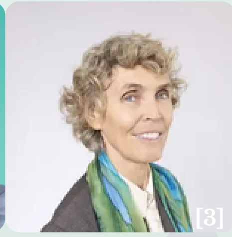


Exploring indoor air quality challenges in non-notified urban slum: A case study from India

Subhashree Mohapatra, Shiva Ji, Jane Burry

Introduction

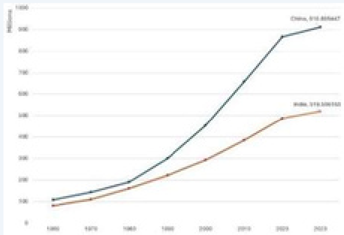
India became the world's most populous country in 2023, yet its urbanisation lags behind China, marked by horizontal expansion into peri-urban areas. This growth has largely been unplanned, pushing low-income migrants into informal settlements with limited infrastructure. Despite a decline in slum percentage, absolute numbers continue to rise, with India projected to have the largest slum population by 2025. These settlements face multiple environmental challenges, particularly indoor air pollution (IAQ), due to poor ventilation, substandard materials, and proximity to roads and industries. Most homes rely on single-sided ventilation, which worsens IAQ by trapping pollutants. While CFD modelling is used to simulate airflow and suggest design improvements, it lacks realism in capturing complex IAQ conditions. To address this, the study integrates CFD with real-time air quality monitoring (PM1, PM2.5, PM10, CO2, HCHO) and qualitative methods to understand how environmental, material, and human factors impact IAQ in slum dwellings.

Methodology

The study was conducted in a non-notified slum cluster in Isnapur, a rapidly urbanising area on the outskirts of Hyderabad. The selected house, built using makeshift materials like bamboo, tin, and tarpaulin, is one of fewer than 50 dwellings occupied by industrial workers without access to formal housing. Over two weeks in March, air quality was monitored using a Prana Air CAIR+ sensor, measuring PM2.5, PM10, CO2, and HCHO. The house, around 60 square feet, shelters a family of three and lacks piped water, sanitation, and space for indoor activities. Qualitative observations and interviews revealed indoor crowding, reliance on LPG for cooking, dusty surroundings, and minimal infrastructure, highlighting typical environmental and structural challenges in such informal settlements.

Results

- PM2.5 and PM10 levels exceeded Class A limits, falling into Class B/C range.
- HCHO levels stayed below Class B threshold but surpassed Class A standards.
- CO2 concentrations consistently crossed Class A limits due to poor ventilation.
- Frying and closed doors during cooking increased indoor pollutant levels.
- Dust entered easily through bamboo mats and unsealed openings.
- CFD showed air getting trapped inside with minimal exit flow.



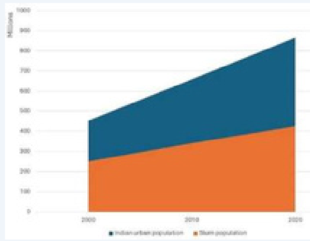


Fig.1.1a. Urban population from 1960-2023 in India and China (WorldBank Group, n.d.-b),1b Urban slum population compared with the overall urban Indian population from 2000-2020(WorldBank Group, n.d.-a)

Fig.2. Exterior of the slum cluster in Isnapur (author)

Fig. 3. Interior pictures with a focus on the equipment used(author)

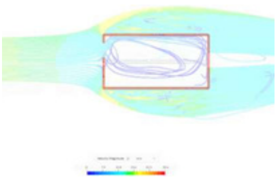
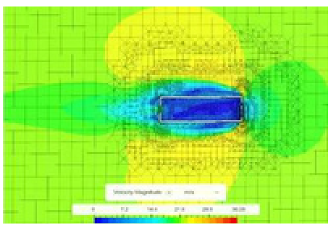


Fig. 7.7a CFD analysis depicting the natural wind movement through the one-sided opening of the door and bamboo mat



7b Air flow with added 06x0.6 metre ventilator with same level of door

Recommendations

- While CFD effectively demonstrates air movement within the structure, it lacks critical elements such as accounting for resident behaviours (e.g., keeping doors open or closed for extended periods), the impact of the surrounding environment (e.g., passing vehicles), and specific health risks like PM1 exposure.
- Real-time monitoring with qualitative data bridges these gaps by capturing dynamic interactions and providing comprehensive insights into pollutant behaviour (Yao et al., 2022).
- Nonetheless, CFD enables recommendations for structural improvements to enhance ventilation.
- For this specific structure, adding a small opening, preferably a ventilator on the wall opposite the door, can help reduce pollutant stagnation and facilitate cross-ventilation as shown in fig. 7b.
- Additionally, sealing gaps near bamboo mats can limit dust infiltration.
- Promoting the use of low-emission construction materials such as mud bricks and advocating for subsidised electric cooking solutions can further improve IAQ.
- Regular cleaning of the roof to remove accumulated dust will aid in low PM.

Conclusion

This study reveals severe IAQ issues in a non-notified urban slum house, driven by poor ventilation, low-quality materials, and daily activities like cooking. PM2.5, PM10, and CO2 levels exceeded Class A standards, while formaldehyde stayed within Class B but above optimal levels. CFD analysis confirmed airflow limitations, supporting recommendations such as adding cross-ventilation and using low-emission materials like mud bricks. The findings underscore the harsher conditions in non-notified slums compared to notified slums and LIG housing. Given that most prior studies focus on Mumbai and notified slums, future research should address non-notified slums in other Indian cities to better inform inclusive housing strategies.

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